UNCLASSIFIED

AD NUMBER

AD295648

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies and their contractors; Foreign Government Information; OCT 1962. Other requests shall be referred to British Embassy, 3100 Massachusetts Avenue, NW, Washington, DC 20008.

AUTHORITY

DSTL, AVIA 6/20051, 13 Aug 2008

THIS PAGE IS UNCLASSIFIED

REPORT
CHEM. 538

ROYAL AIRCRAFT ESTABLISHMENT

(FARNBOROUGH)

REPORT No. CHEM. 538

THERMAL EMISSIVITIES OF SOME METALLIC AND NON-METALLIC SURFACES OVER THE RANGE OF TEMPERATURE 70°C TO 250°C

by

W. G. D. Carpenter, A.R.I.C. and J. H. Sewell

OCTOBER, 1962

MINISTRY OF AVIATION, LONDON, W.C.2

U.D.C. No. 543.423 : 546.3 : 546.1

Report No. Chem 538
October, 1962

ROYAL AIRCRAFT ESTABLISHMENT

(FARNBOROUGH)

THERMAL EMISSIVITIES OF SOME METALLIC AND NON-METALLIC SURFACES OVER THE RANGE OF TEMPERATURE 70°C TO 250°C

by

W. G. D. Carpenter, A.R.I.C.
and
J. H. Sewell

RAE Ref: Chem 882/WGDC

SUMMARY

Thermal emissivities of some metallic surfaces, of various metallic surface treatments and of non-metallic (paint) finishes have been measured over the temperature range 70°C to 250°C. The emissivities of polished and vapour-blasted metallic surfaces were found to be low, whilst anodised aluminium gave high values. All the paint finishes tested had high emissivities except those containing a metal pigment.

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

1 INTRODUCTION

The heat absorbed by aircraft as a result of high speed flight is dissipated in part by radiation. Likewise, in the case of a satellite, the heat absorbed from the sun, from other reflecting bodies and from sources within the vehicle is re-emitted, in the absence of atmosphere, by radiation only.

The rate of heat loss by radiation in all directions from a surface at a given temperature is defined as the total hemispherical emissivity of that surface, at that temperature. In this report it is expressed as the ratio of the actual rate of heat loss of the surface to the theoretical rate of heat loss of a black body, under identical conditions.

The emissivities of a number of metallic surfaces with various treatments and with non-metallic coatings (paints) have been measured between 70°C and 250°C.

2 METHOD OF TEST

There are a number of established methods for measuring the total hemispherical emissivity of a surface. Reference 1 describes some of these briefly. Details of the method used in obtaining the results given in this report are the subject of a previous report[2]. The principle of the apparatus is to compare the rate of cooling of a surface with that of a theoretical black body under identical conditions. Results to an accuracy of ±3% may be achieved.

3 THERMAL EMISSIVITIES OF METALLIC SURFACES

3.1 Polished surfaces

The metals under examination were copper, aluminium, magnesium and stainless steel (British Standard Specification S.110). Cubes of these materials were fitted with heater coils, as described in a previous report[2], and polished carefully by hand.

The thermal emissivity of a metallic surface depends on the nature of the metal and on its degree of polish. Absolute emissivity values for these surfaces are therefore somewhat arbitrary unless the surfaces can be made as smooth as are theoretically possible. As this is impracticable, results quoted in this report should be taken as a guide to the emissivity achieved when a "normal" polish is attained. The metals described as "polished", with the exception of the stainless steel, were finished by hand using fine abrasive papers, followed by application of a metal polish. The stainless steel was in a good state of finish, as received, and was too hard for further improvement by hand polishing techniques.

3.2 Treated surfaces

Various metal treatments, apart from polishing, have been studied to assess their influence on emissivity values, and details of these are described in the following paragraphs.

Gold, because of its stability under adverse environmental conditions, would appear to be a useful material for certain satellite applications. Gold leaf (6 microns thick) was examined as a coating on a copper cube, being attached to the copper by means of a resin coating of known high emissivity. Any effect of such a substrate on a thin surface of low emissivity, such as gold, would thus be made apparent.

Vapour-blasting is a process similar to sand-blasting in effect but of a less vigorous character. In the former process, particles of alumina are suspended in water whilst being directed under pressure to the metal surface. Aluminium and magnesium (after being hand polished as described in 3.1) and stainless steel cubes, were subjected to vapour-blasting treatment to obtain surfaces which would simulate the accumulated effect of continual bombardment by space particles, such as cosmic dust, of a satellite surface. Emissivity values were measured on several aluminium specimens which had been vapour-blasted over differing intervals of time.

To examine the possibility of emissivity control by spray coating, measurements were made of an aluminium cube covered with a deposit of aluminium by means of a wire pistol as described in Specification DTD.906. The thickness of this deposit was nominally 0·005 to 0·008 in.

Another coating thought to be of special value for emissivity control of a satellite surface was an anodic finish. An aluminium cube was, therefore, treated by the sulphuric acid anodising process as described in Specification DTD.910 and its emissivity compared with that of the polished metal. Vapour blasting of an anodised surface was also examined to observe any likely change in the emissivity of the oxide coating.

4 THERMAL EMISSIVITIES OF NON-METALLIC SURFACES

Paints are coatings consisting of pigments suspended in resins or other clear media. Among the paints selected for the series of emissivity measurements were proprietary materials which contained titanium dioxide or aluminium pigments in epoxide or nitrocellulose media. Experimental paints contained titanium pyrophosphate or zirconium dioxide in a nitrocellulose medium. These paints were applied directly onto copper cubes.

A special proprietary titanium dioxide/acrylic paint was also included. This was applied over a special primer which was coated on to an aluminium cube. The emissivity of this paint was measured soon after application, and also after exposing it to a temperature of 150°C for 2000 hours. This simulated the effect of aging on the emissivity of a painted surface of a proposed supersonic airliner.

All paint films were approximately 0·003 in. thick.

In addition to the paints, the emissivities of the separate clear media were measured so that the effect of pigment inclusions could be ascertained.

5 DISCUSSION OF RESULTS

Results are illustrated in Figs.1-8.

All the polished metals had low emissivities, which did not vary appreciably over the range of temperature examined (Figs.1,2,3 and 4). A vapour-blasted aluminium, magnesium or stainless steel surface always had a higher emissivity than that of the corresponding polished metal (Figs.2,3 and 4); this is to be expected, as the surface area is effectively increased by the blasting. An aluminium surface had a higher emissivity after vapour-blasting for 2 minutes than it did after vapour-blasting for only 20 seconds (Fig.2). However, a similar surface which had been vapour-blasted for 10 minutes had a lower emissivity than one after 2 minutes treatment. The emissivity achieved by vapour-blasting is dependent on the state of the surface at completion of the blasting and control by the process does not appear practical.

The emissivity of a sprayed aluminium surface was similar to that obtained by vapour-blasting the polished metal (Fig.2).

Gold leaf had a higher emissivity than was expected from published data on the emissivity of massive gold (Fig.1). The leaf was thin enough to transmit visible wavelengths, particularly green light; also a number of pin holes were present. The influence of the adhesive resin must therefore have contributed to this increased value. The crinkly nature of the leaf also increased its superficial area, and thus again increased the apparent emissivity.

Anodic films on aluminium surfaces had high emissivities (Fig.5) but unlike the effect on polished metallic surfaces, vapour-blasting decreased the emissivity somewhat by apparently smoothing the hard surface rather than by indenting it.

All the paint films tested (Figs.6, 7 and 8) apart from the aluminium paint finish, had high emissivities at the temperatures of measurement, the emissivity falling as the temperature was increased. The unpigmented clear media (Figs.7 and 8) also gave fairly high values. Thus, the presence of non-metallic pigment makes little contribution to the emissivity of the paint. An aluminium paint (Fig.6), on the other hand, gave results approximately half way between that of polished aluminium and that of the paint medium. The proprietary titanium dioxide/acrylic paint showed little change in emissivity after heating for 2000 hours at 150°C compared with the value obtained for the freshly prepared coating.

6 CONCLUSIONS

Polished metals have low emissivities, but when roughening occurs as in the case of vapour-blasting, emissivities increase. This may be mainly attributed to the increase in superficial area. Anodic treatment of an aluminium alloy surface results in a marked increase in emissivity from below 0·2 for the polished metal to between 0·75 and 0·9, with the anodic coating, over the range of temperatures concerned.

All paint media and paint finishes examined gave high emissivities within the experimental temperature range, the values usually decreasing with increase in temperature. The exception to this general rule of high emissivity for paints was where a metallic pigment was incorporated; an aluminium-pigmented

nitrocellulose paint, for example, gave a value of approximately 0·5. A non-metallic coating having a low emissivity has not yet been found. It would appear that, for the temperature control of a given body such as a space vehicle, any emissivity could be provided by careful control of the type of finish and of the extent to which the area of the surface of the item is coated. For example, in those applications where the use of a paint coating is impractical or undesirable, an aluminium surface, part anodised and part polished, would give a controlled emissivity value between, say, 0·2 and 0·75.

LIST OF REFERENCES

No.	Author(s)	Title, etc
1	Wood, W.D., Deem, H.W., Lucks, C.F.	Methods of measuring emittance. Defense Metals Information Center Memorandum 78, 27th Dec. 1960. Battelle Memorial Institute.
2	Carpenter, W.G.D., Sewell, J.H.	An apparatus for measuring the thermal emissivity of metal surfaces and surface finishes. R.A.E. Report No. Chem 528, February 1962.

ATTACHED:-

Drg Nos. CH 4144 to 4151
Detachable abstract cards

ADVANCE DISTRIBUTION:-

DCA(RD)		Director, RAE
DGSR(A)		DDRAE(A)
DGAGS		DDRAE(E)
D Mat		Head of Aero Dept
DNGTE (for Dr. R.N.C.Strain)		Head of ME Dept
AD Mat NM		Head of Met Phys Dept
SMR, Mat Res Labs, Waltham Abbey		Head of Structures Dept
ADAI Mat (Harefield)		Head of Radio Dept
Mat 8		Head of Space Dept
TIL	120	Pats 1/RAE
		Library

CH. 4144

REPORT CHEM. 538.
FIG. 1.

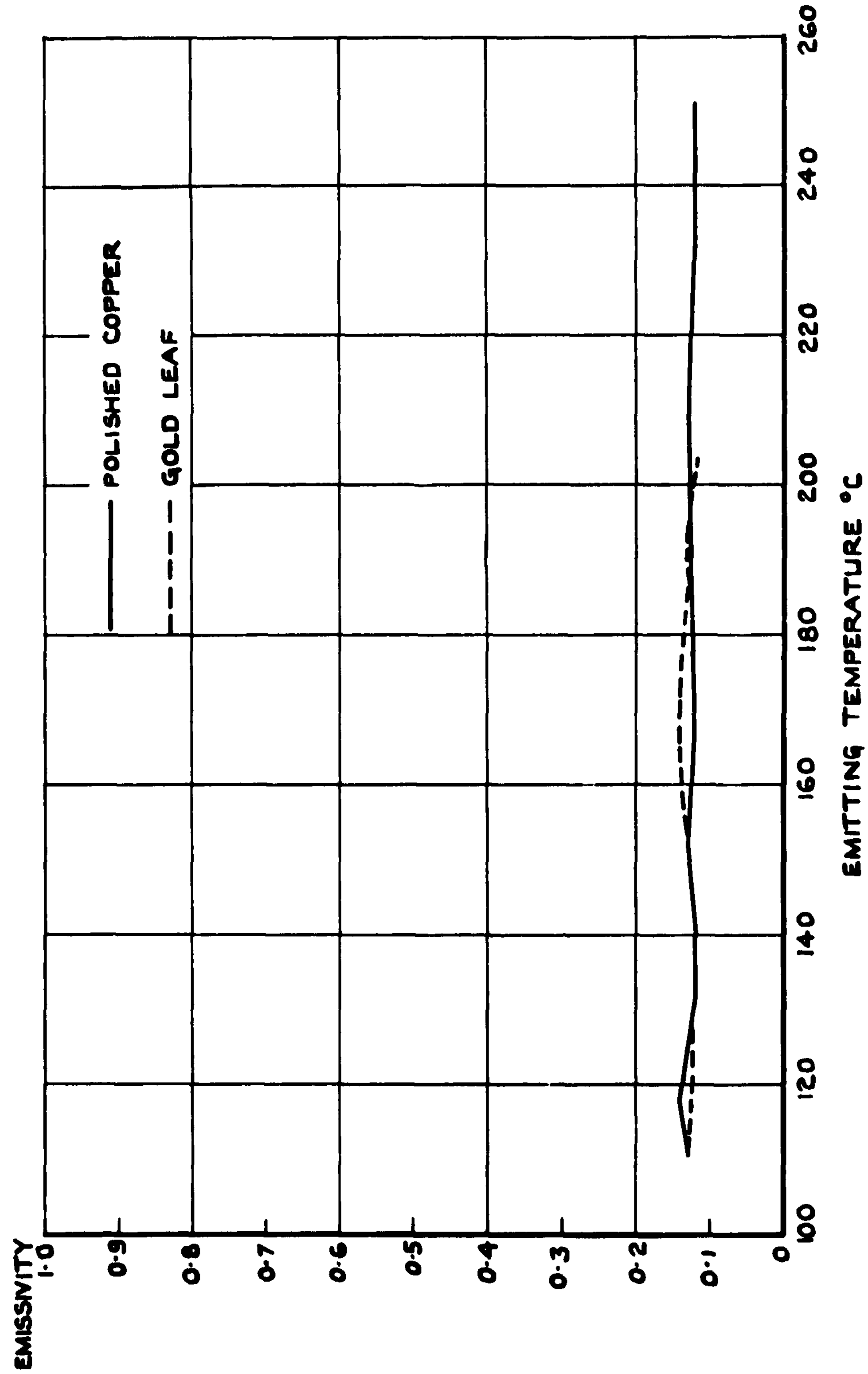

FIG.1. THERMAL EMISSIVITIES OF POLISHED COPPER AND GOLD LEAF.

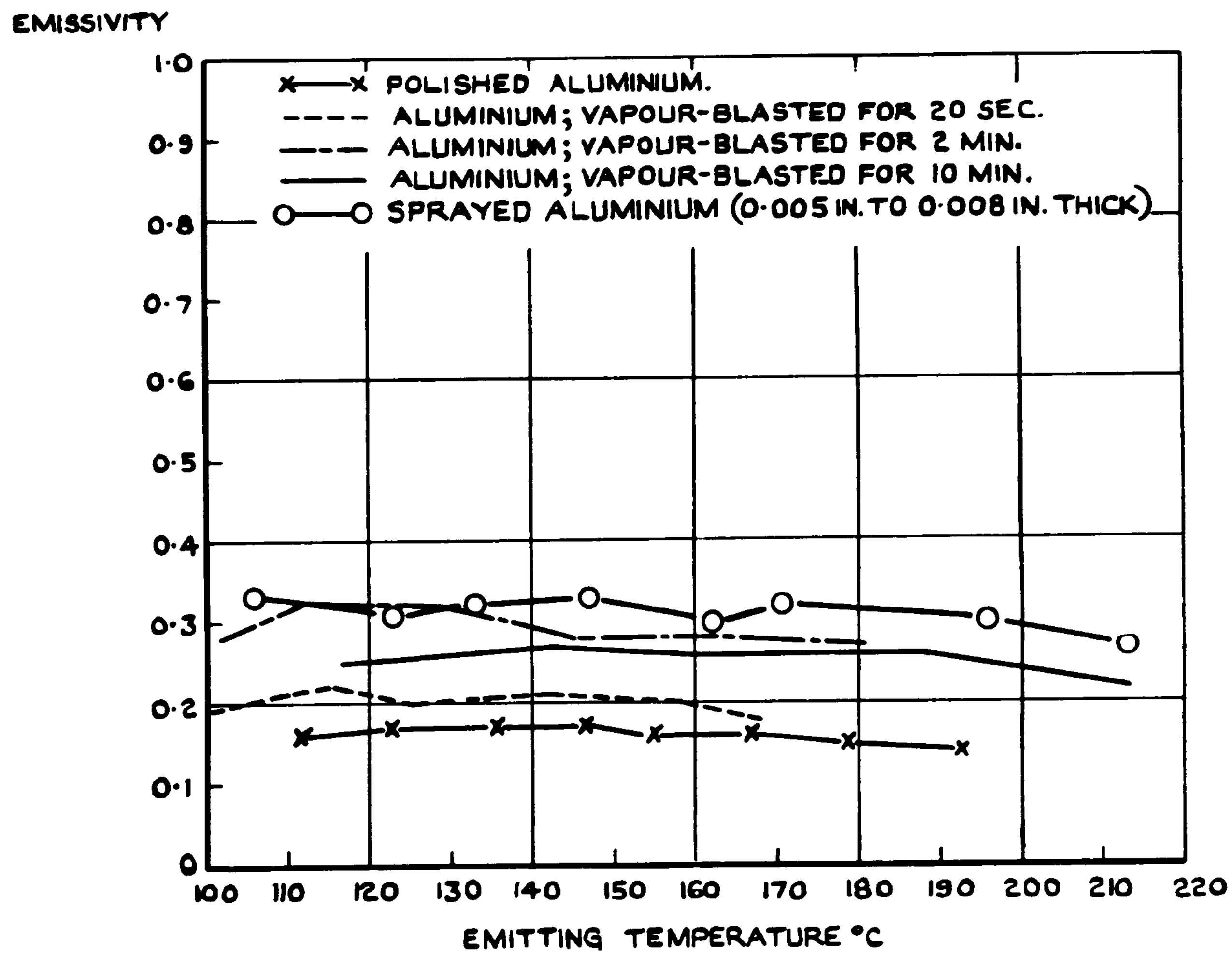

FIG.2. THERMAL EMISSIVITIES OF POLISHED ALUMINIUM, VAPOUR-BLASTED ALUMINIUM & SPRAYED ALUMINIUM.

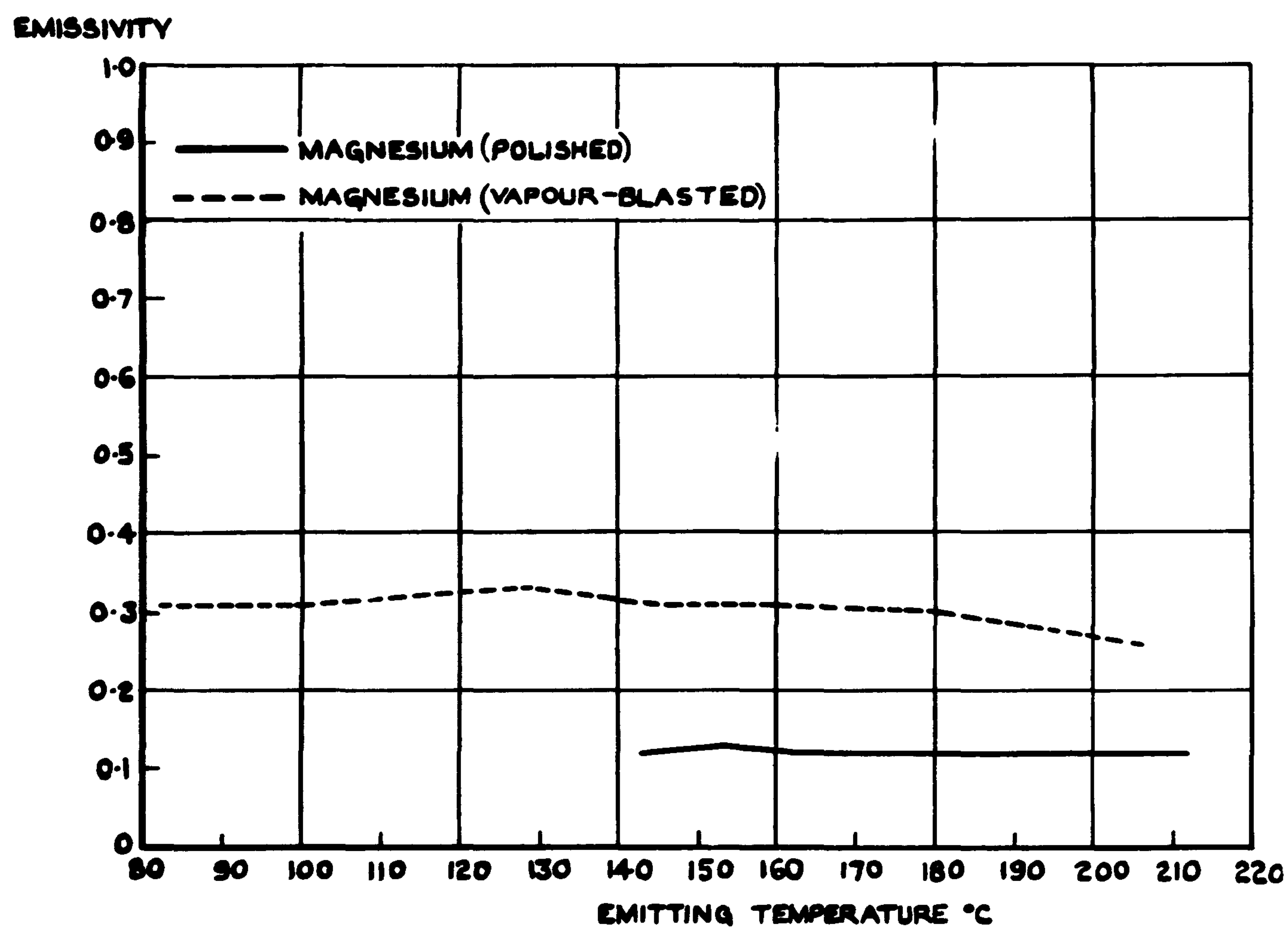

FIG. 3. THERMAL EMISSIVITIES OF POLISHED & VAPOUR-BLASTED MAGNESIUM.

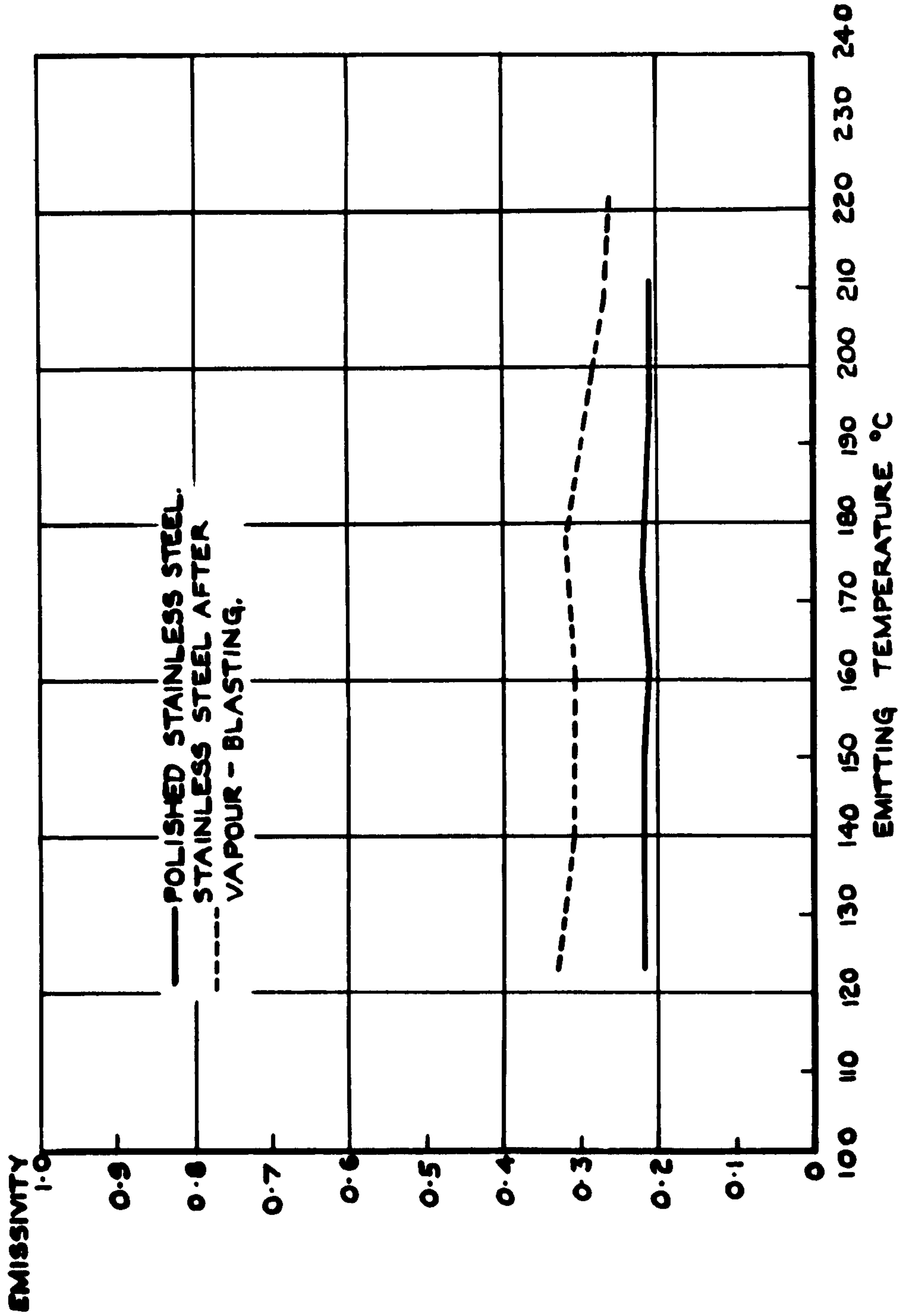

FIG.4. THERMAL EMISSIVITIES OF POLISHED & VAPOUR-BLASTED STAINLESS STEEL (S·110).

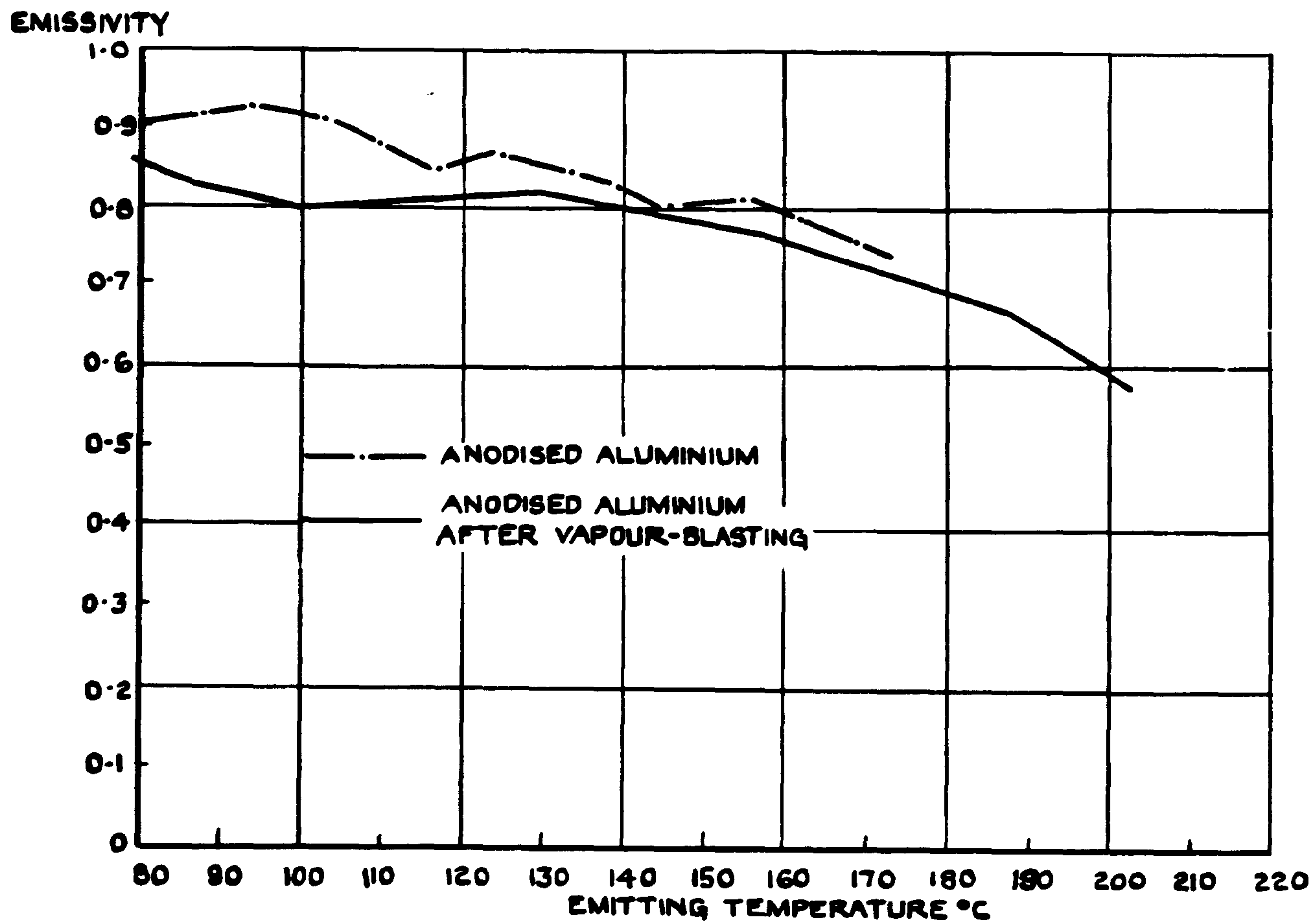

FIG.5. THERMAL EMISSIVITIES OF ANODISED ALUMINIUM BEFORE & AFTER VAPOUR-BLASTING.

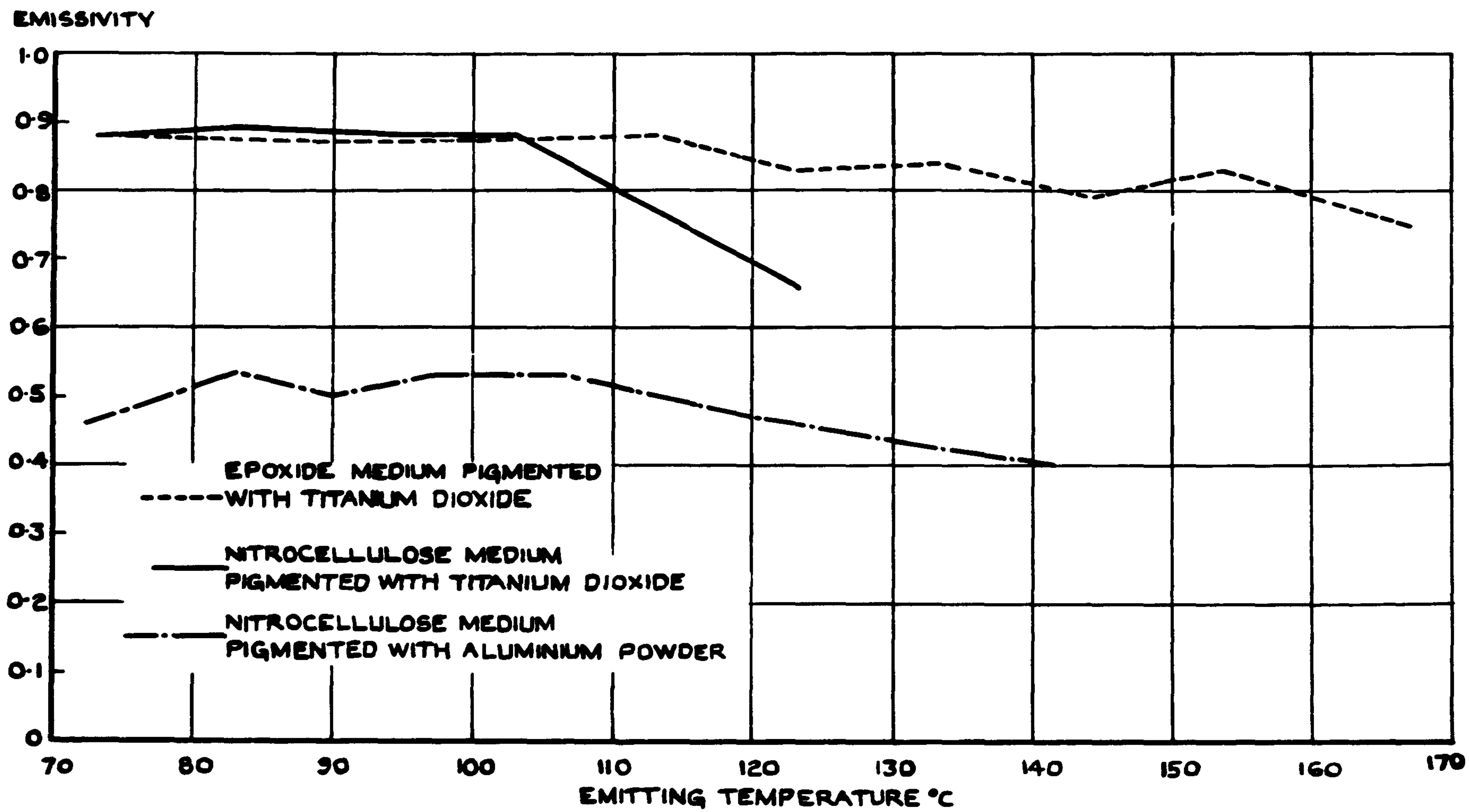

FIG. 6. THERMAL EMISSIVITIES OF PROPRIETARY PAINTS.

CH. 4150

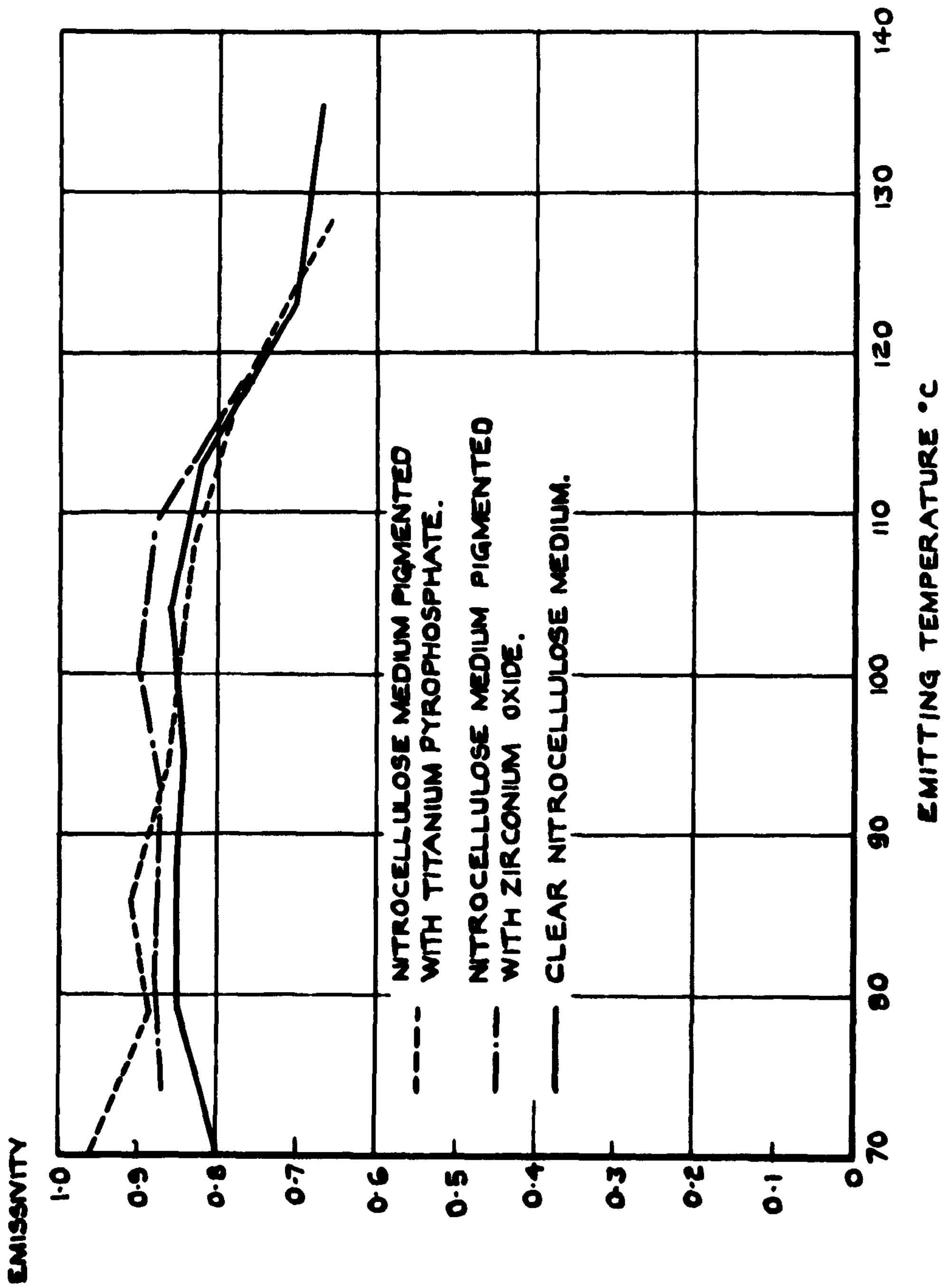

FIG. 7. THERMAL EMISSIVITIES OF EXPERIMENTAL WHITE PAINTS.

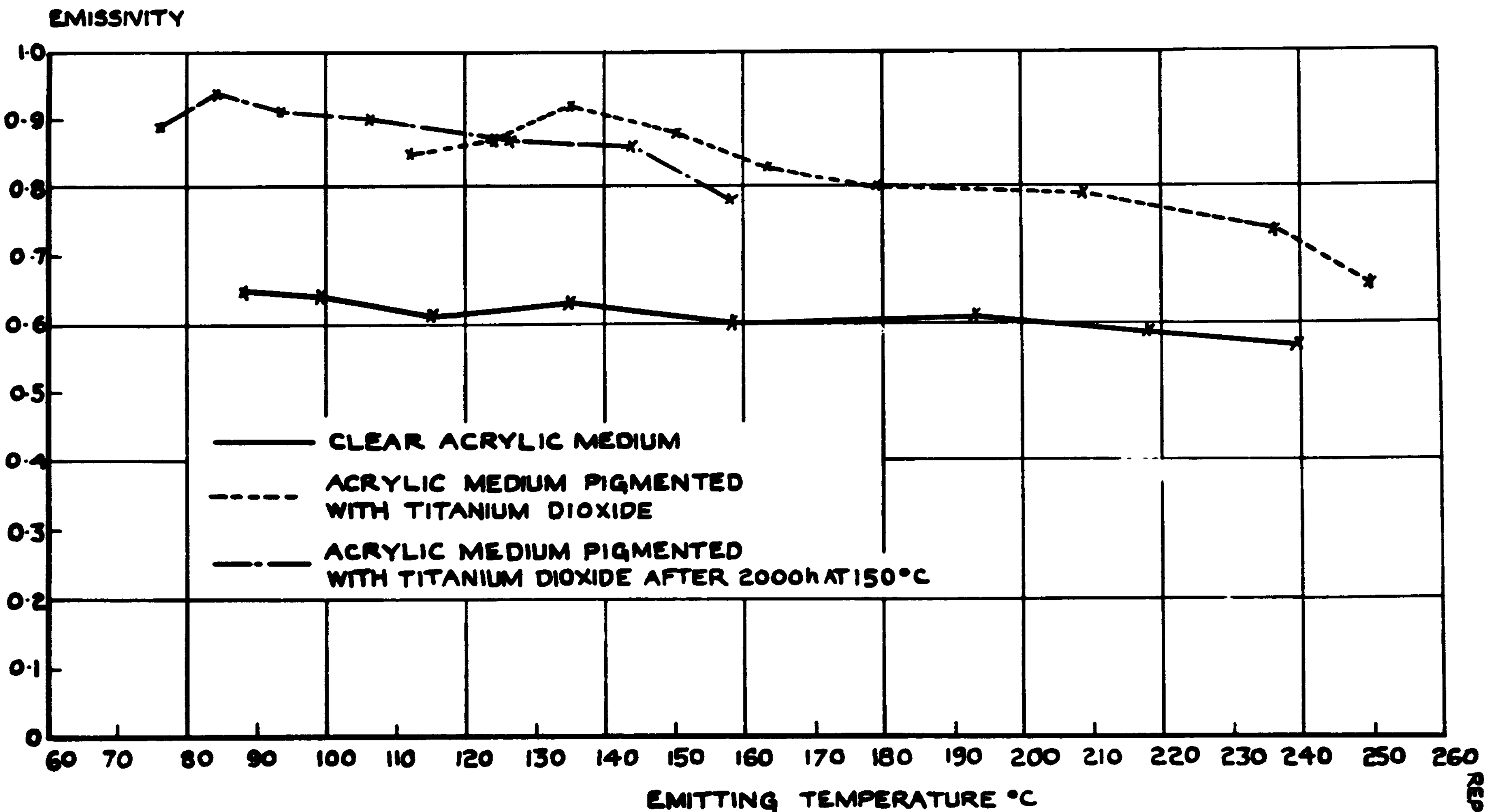

FIG. 8. THERMAL EMISSIVITIES OF PAINTS INCORPORATING AN ACRYLIC RESIN AS A MEDIUM & THE EFFECT OF AGING AT TEMPERATURE.

DETACHABLE ABSTRACT CARDS

These abstract cards are inserted in Reports and Technical Notes for the convenience of Librarians and others who need to maintain an Information Index.

UNCLASSIFIED

Report No. Chem 538 — 543.423 : 546.3 : 546.1
Royal Aircraft Establishment

THERMAL EMISSIVITIES OF SOME METALLIC AND NON-METALLIC SURFACES OVER THE RANGE OF TEMPERATURE 70°C TO 250°C.
Carpenter, W. G. D. and Sewell, J. H. October, 1962.

Thermal emissivities of some metallic surfaces, of various metallic surface treatments and of non-metallic (paint) finishes have been measured over the temperature range 70°C to 250°C. The emissivities of polished and vapour-blasted metallic surfaces were found to be low, whilst anodised aluminium gave high values. All the paint finishes tested had high emissivities except those containing a metal pigment.

UNCLASSIFIED

UNCLASSIFIED

Report No. Chem 538 — 543.423 : 546.3 : 546.1
Royal Aircraft Establishment

THERMAL EMISSIVITIES OF SOME METALLIC AND NON-METALLIC SURFACES OVER THE RANGE OF TEMPERATURE 70°C TO 250°C.
Carpenter, W. G. D. and Sewell, J. H. October, 1962.

Thermal emissivities of some metallic surfaces, of various metallic surface treatments and of non-metallic (paint) finishes have been measured over the temperature range 70°C to 250°C. The emissivities of polished and vapour-blasted metallic surfaces were found to be low, whilst anodised aluminium gave high values. All the paint finishes tested had high emissivities except those containing a metal pigment.

UNCLASSIFIED

UNCLASSIFIED

Report No. Chem 538 — 543.423 : 546.3 : 546.1
Royal Aircraft Establishment

THERMAL EMISSIVITIES OF SOME METALLIC AND NON-METALLIC SURFACES OVER THE RANGE OF TEMPERATURE 70°C TO 250°C.
Carpenter, W. G. D. and Sewell, J. H. October, 1962.

Thermal emissivities of some metallic surfaces, of various metallic surface treatments and of non-metallic (paint) finishes have been measured over the temperature range 70°C to 250°C. The emissivities of polished and vapour-blasted metallic surfaces were found to be low, whilst anodised aluminium gave high values. All the paint finishes tested had high emissivities except those containing a metal pigment.

UNCLASSIFIED

UNCLASSIFIED

Report No. Chem 538 — 543.423 : 546.3 : 546.1
Royal Aircraft Establishment

THERMAL EMISSIVITIES OF SOME METALLIC AND NON-METALLIC SURFACES OVER THE RANGE OF TEMPERATURE 70°C TO 250°C.
Carpenter, W. G. D. and Sewell, J. H. October, 1962.

Thermal emissivities of some metallic surfaces, of various metallic surface treatments and of non-metallic (paint) finishes have been measured over the temperature range 70°C to 250°C. The emissivities of polished and vapour-blasted metallic surfaces were found to be low, whilst anodised aluminium gave high values. All the paint finishes tested had high emissivities except those containing a metal pigment.

UNCLASSIFIED

[dstl]

Information Centre
Knowledge Services
[dstl] Porton Down,
Salisbury
Wilts
SP4 0JQ
22060-6218
Tel: 01980-613753
Fax 01980-613970

Defense Technical Information Center (DTIC)
8725 John J. Kingman Road, Suit 0944
Fort Belvoir, VA 22060-6218
U.S.A.

AD#: AD295648

Date of Search: 13 August 2008

Record Summary: AVIA 6/20051
Title: Thermal emissivities of some metallic and non-metallic surfaces over the range of temperature 70°C to 250°C
Availability Open Document, Open Description, Normal Closure before FOI Act: 30 years
Former reference (Department) REPORTS CHEM 538
Held by The National Archives, Kew

This document is now available at the National Archives, Kew, Surrey, United Kingdom.

DTIC has checked the National Archives Catalogue website (http://www.nationalarchives.gov.uk) and found the document is available and releasable to the public.

Access to UK public records is governed by statute, namely the Public Records Act, 1958, and the Public Records Act, 1967.
The document has been released under the 30 year rule.
(The vast majority of records selected for permanent preservation are made available to the public when they are 30 years old. This is commonly referred to as the 30 year rule and was established by the Public Records Act of 1967).

This document may be treated as UNLIMITED.